AD-A214 123

The Effects of Abrupt Topography on Ocean Currents as Sensed by Satellite Remote Sensing

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Introduction

The objective of this ~~research~~ project is to use a variety of remote sensing methods to study the interaction between ~~the~~ ocean circulation and the abrupt bottom topography at the location of Fieberling seamount in the eastern Pacific Ocean (west of Los [illegible]). In support of these satellite measurements the project includes the collection of ship-borne XBT surveys of the area around the Fieberling seamount.

The satellite data tools being studied are the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA/TIROS-N weather satellites and the RADAR altimeter on the GEOSAT satellite. The AVHRR data can be processed to produce 1 km resolution images of sea surface temperature (SST) from the infrared AVHRR channels. Sequential SST images can be used to estimate ~~the~~ surface currents from ~~the~~ advection of the surface temperature patterns.

The GEOSAT altimetry can be used to monitor the temporal changes of the sea surface elevation which can then be converted to estimates of the changes in geostrophic currents. Thus the 2 years of GEOSAT data available supply a valuable picture of the changes in the geostrophic currents in the area around Fieberling. Keywords: Sea height [illegible]; Bathymetry [illegible] Satellite [illegible] [illegible] bottom topography; Meteorological satellites. (EDC)

Project Status

1. AVHRR Analysis

The area around Fieberling has proven to be one of the cloudiest regions in the world. Continued monitoring of the AVHRR imagery in the

region has provided fewer than 6 partially clear images over a 6 week period. Located 300 miles west of San Diego the seamount is at the eastern edge of the marine stratus layer that creates a persistent cloud cover in the region. For this reason it has not been possible to collect a sequence of even partly clear AVHRR images in the Fieberling region. A search through 18 months of daily AVHRR images from Redwood City, Calif., yielded only 6 total images that were sufficiently clear to be able to see the area immediately around Fieberling.

We are presently using the AVHRR imagery that we have collected since Oct. 1988 from our own antenna, along with the historical data from the Redwood City archive, to classify the SST length scales in the imagery and decide if there is a scale relationship between the SST field and the topography of Fieberling. In addition we are working to produce relatively cloud-free composites from short series of images. These composites will be further smoothed to provide a mean picture of the SST field which will also be analyzed for length scales typical of the local SST patterns.

2. GEOSAT altimetry analysis

We have acquired time series of 2 years of GEOSAT data from Bob Cheney for the are around Fieberling. These data are gridded in 1 by 2 degree squares for the 17-day repeat cycle of GEOSAT. Computations of the sea surface variability have shown an interesting pattern around Fieberling which suggests the role of the bottom topography in generating pairs of cyclonic and anticyclonic ocean eddies. RMS variability plots for the annual and seasonal means have demonstrated the seasonal progression of the altimeter signal.

An empirical orthogonal function (EOF) analysis of the gridded

GEOSAT data required the first 3 functions to explain a substantial portion of the sea surface variance. The pattern of the most significant EOF's was similar in character to that see in the RMS variability plots with pairs of matched, counter-rotating eddies in the area around Fieberling. Finally a frequency-wavenumber spectral analysis of the gridded GEOSAT data revealed dominant features of the GEOSAT field with time and length scales consistent with Rossby wave dynamics.

At present a fit to the raw GEOSAT data over a variety of frequencies is being carried out to be able to depict the time series of surface variability. A movie of the surface features over Fieberling show again a variety of mesoscale structures around Fieberling which propagate to the west over the 2 years of 17-day repeat data. More study is needed to determine the relationship between these mesoscale eddy features and the location/size of Fieberling itself.

3. XBT Surveys

Three XBT surveys have been collected in the Fieberling region. The first was part of a mid-May cruise from Honolulu to San Diego which spent about 2-3 weeks in the Fieberling region conducting geological studies. A student from CCAR (Carol-Ann Clayson) carried out an XBT survey of the area from which the upper-layer geostrophic currents have been calculated and mapped. Again the dominant feature is the high level of mesoscale structure in the region immediately around Fieberling. As with the GEOSAT variability studies Fieberling appears to be located between matched, counter-rotating eddies.

Two more XBT surveys have been collected on the Sept. New Horizon cruise. These data are presently being processed.

Future Plans

We plan to continue to collect all available AVHRR imagery which are sufficiently cloud-free to see the Fieberling region. We will also continue the analysis of GEOSAT data to better understand the nature of the features mapped and how they relate to bottom topography. Finally we plan a number of additional XBT surveys in the next field season.

Appendix A

Science report submitted to project manager.

GEOSAT Altimetry, XBT Surveys and Satellite Imagery

by

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We have used the GEOSAT altimeter data as prepared into time series of variability by Cheney and Douglas (NOAA GEOSAT). These time series of surface height variability are computed for 1-degree latitude and 2-degree longitude squares and are averaged over two days. These [illegible] from Nov., 86 to late 1988 providing series of about 2 years of data. The time series have been corrected for many of the error terms common with satellite altimetry data.

RMS plots

To examine the patterns of *variability* we have plotted the Root-Mean-Square (RMS) variability from the GEOSAT series over the area around Fieberling (about a 10 degree square). The overall (total 2-year time series) map in Fig. 1 shows Fieberling (the cross) in the middle of a strong zonal gradient of surface height variability. This means that the area to the south of Fieberling varies more than the area to the north and that the bulls-eye to the south is a center of maximum variability while the similar ellipse to the north is a point of minimum variability. One might think that if the general flow is from the northeast that the maximum variability to the southwest of Fieberling might be a result of the interaction of the topography with the flow.

The scales of the features are also very interesting. The maximum feature near Fieberling in Fig. 1 has a diameter of about 100-200 km which is consistent with the baroclinic eddies that occur in this area. There is a lot of speculation that these eddies are the expressions of westward travelling Rossby waves and this might be the case where here we have a baroclinic feature that may have been the consequence of the barotropic interaction between the topography and the flow.

It is also interesting that there is a definite seasonal fluctuation to the RMS surface height variability pattern (Figs. 2-5). The summer map (Fig. 2) exhibits a southward shift of the zonal gradient away from Fieberling. The variability maximum to the south of Fieberling is stronger than in Fig. 1 and is shifted to the west a bit. In fall (Fig. 3) the gradient again moves north to include Fieberling but now is oriented more to the northwest than the zonal pattern in the overall structure. There is also no clear maximum to the south as seen earlier while to the north the strong feature one sees is now a maximum. Winter (Fig. 4) looks like the overall mean (Fig. 1) as does the spring pattern in Fig. 5. These seasonal variations in sea surface variability are likely the result of seasonal changes in the seasonal mean currents and their interaction with the steep topography of Fieberling.

There are also important interannual changes as seen in the two different winter patterns of 1986 (Fig. 6) and 1987 (Fig. 7). In both of these there is the maximum to the southwest of Fieberling but the features to the north of Fieberling are very different in the two years. Clearly the changes in the interaction between current and topography have both seasonal and interannual fluctuations which express themselves in the time/space variability of the sea surface. It is interesting to note the persistence in the location of Fieberling in the gradient between the maximum and minimum values of surface height variability. Also the scales of these maxima and minima are consistent from period to period suggesting that the same mechanism may be responsible for their existence and that the variability is due to a change in the forcing functions with year and season.

Empirical Orthogonal Functions (EOF's)

The EOF representation of the surface height variability is very interesting since it does not show the same pattern as the RMS variability in the lowest EOF. The first orthogonal function (Fig. 8) explains less than 40% of the variance and while it shows Fieberling to be located in the primarily zonal gradient between positive and negative values the strongest maxima and minima are located upstream instead of downstream (presumed current from the northeast) of Fieberling. Not until the 2nd (Fig. 9) and 3rd (Fig. 10) EOF's do we see the patterns typical of the RMS maps shown earlier. As with the RMS maps these higher EOF's

show Fieberling located in a gradient between features of opposing sign. More work needs to be done to better resolve the significance of these EOF patterns and to try and match the patterns to the possible mechanisms causing them.

Frequency-wavenumber Spectra

Using the spatial array of 2-year times series (of sea surface variability) we computed 2-dimensional frequency-wavenumber spectra. Here we examined only the spatial variability along a line of latitude. The frequency-wavenumber spectrum along the latitude of Fieberling is shown here in Fig. 11. Only positive frequencies are presented while wavenumber can be both positive (eastward) and negative (westward). This plot is dominated by a maximum at periods of about 5-6 months and the lowest possible negative wavenumbers. A smaller maximum also occurs at about 3 months and positive low-wavenumbers; the former may be indications of the westward travelling Rossby waves.

May 18-22, 1989 XBT Survey of Fieberling

As part of the May geology cruise to Fieberling and XBT survey was conducted in the area by a CCAR graduate student Carol Ann Clayson. The pattern of XBT drops is shown here in Fig. 12; the long line off to the northwest is along a GEOSAT tracks line.

The depth of the 12 ^{o}C isotherm from this XBT survey is presented in Fig. 13 with the position of Fieberling marked with a plus (+) sign. It is interesting to note that Fieberling is again in the space between a low and high features which correspond to a cyclonic eddy to the north and a smaller anticyclonic eddy to the south. Both of these features are slightly to the west (downstream?) of Fieberling. Similar mesoscale features can be found in the 0/400 m (Fig. 14) and 0/700 m (Fig. 15) dynamic topographies computed from the XBT data and climatological TS curves. The shallow reference level was used since the top of Fieberling restricts the samples to less than 500 m. Even in this shallow field the pair of mesoscale features is readily apparent with the larger cyclonic (a surface height low) to the north and the smaller anticyclonic cell (a surface high) to the south; again both features are slightly to the west of Fieberling's center. The 700 m reference level topography (Fig. 15) more closely

resembles the isotherm depth in Fig. 13. The northern cyclonic eddy is not as well developed which is consistent with its weaker signature in Fig. 14.

The similarities between the pattern of this XBT survey and the results of the GEOSAT variability analysis are striking. If the mesoscale features, in Figs. 13-15, are generated in response to Fieberling's presence they could be responsible for the higher amplitude variability signatures found around Fieberling in the analysis of the GEOSAT height data. Hopefully the current meter mooring will shed some added light on the temporal variability of these mesoscale features or at least their current signatures in the region. The repeated XBT and CTD surveys planned for the area should help to establish the evolutionary patterns and lifetimes of these mesoscale features.

Infrared Satellite Imagery

Unfortunately Fieberling is located at the eastern edge of the Marine Stratus zone where clouds persistently cover the region. This Marine Stratus layer forms at the seaward boundary of the coastal region and is well know for its persistent cloud cover at least in cirrus bands. The FIRE (First ISCCP Regional Exp) was carried out in this region due to the predictability of seeing clouds in the area. These persistent clouds have made it impossible to pick up regular imagery of the region. We have tried to search through what saved data there are available and have not found even a very good image to work with.

In addition we have picked up the satellite image every day for about 6 months and we have fewer than 1-2 relatively clear images each month. None of these images corresponds with a subsequent mate (a successive clear image) that could be used to compute the surface advection from the displacement of sea surface temperature (SST) features. Thus we have had to settle for a few marginally clear images of the important area around Fieberling. Such as image is shown here as Figs. 16a and 16b. In the first picture we display a contour line version of the 10 micron infrared (channel 4) image for the are around Fieberling. As indicated on the diagram Fieberling is located in the center western portion of the field.

The area immediate surrounding Fieberling appears to be significantly warmer than the general surroundings. This tongue of warm

water suggests again a possible interaction between the surface temperature (likely caused by currents) and the abrupt topography of the Fieberling seamount. Unfortunately we have not been able to collect any more images that is even this clear in the regions and therefore do not know if this pattern repeats. A gray-shade version of the image is shown in Fig. 16 to provide the reader with a clear description of where the warm and cold patches are.

RMS(11/86-8/88) of sea surface height differences

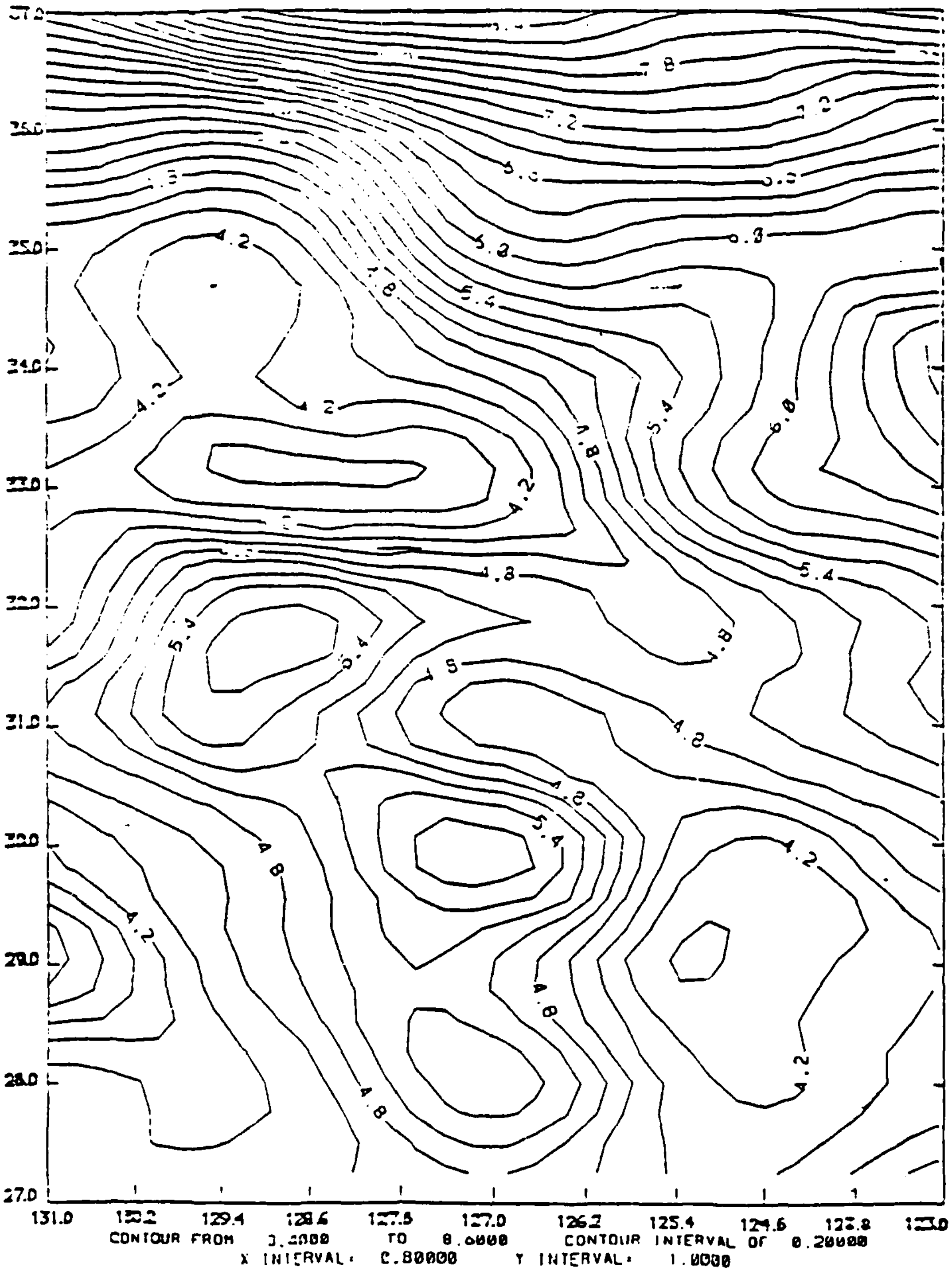


Fig. 1

RMS(summer) of sea surface height

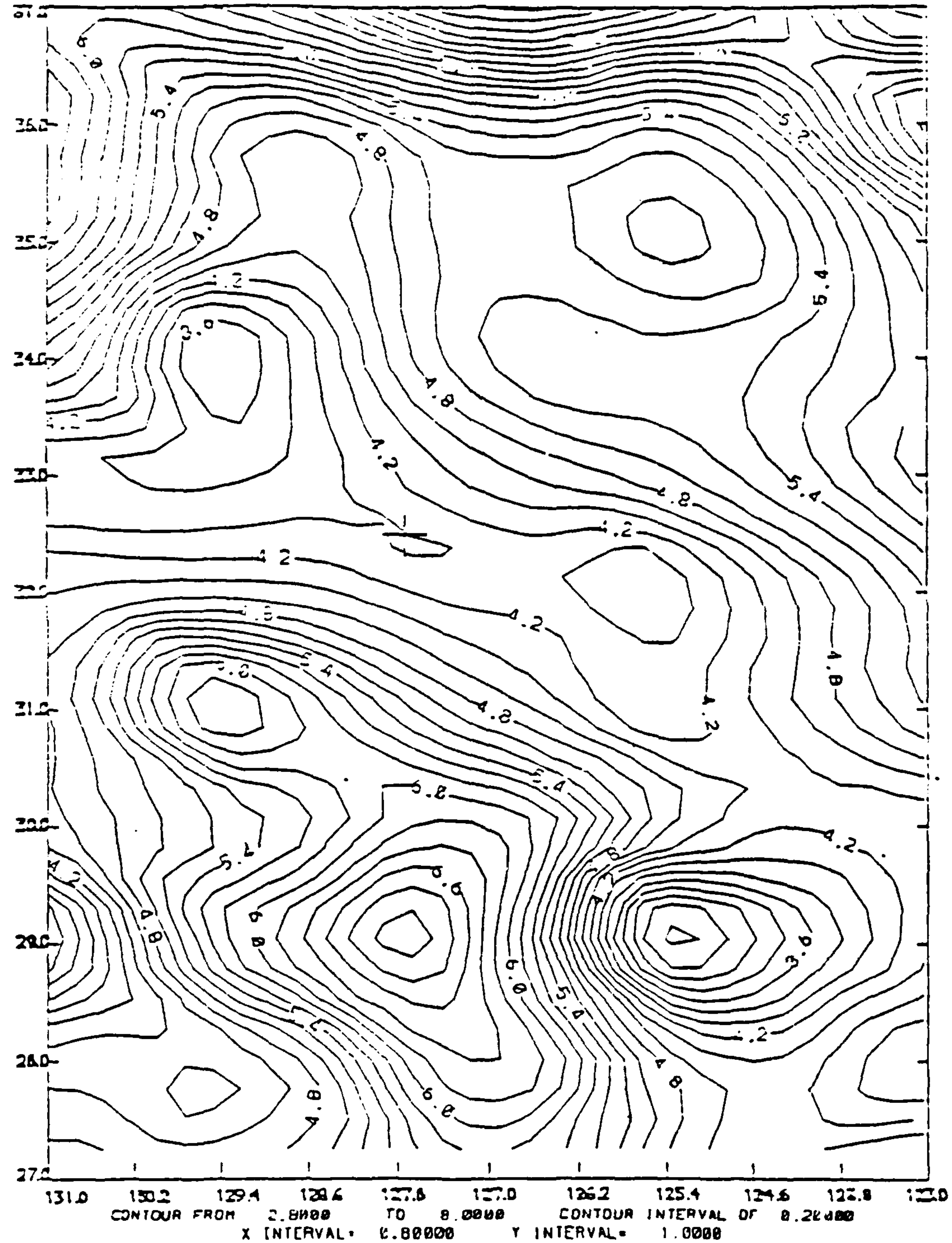
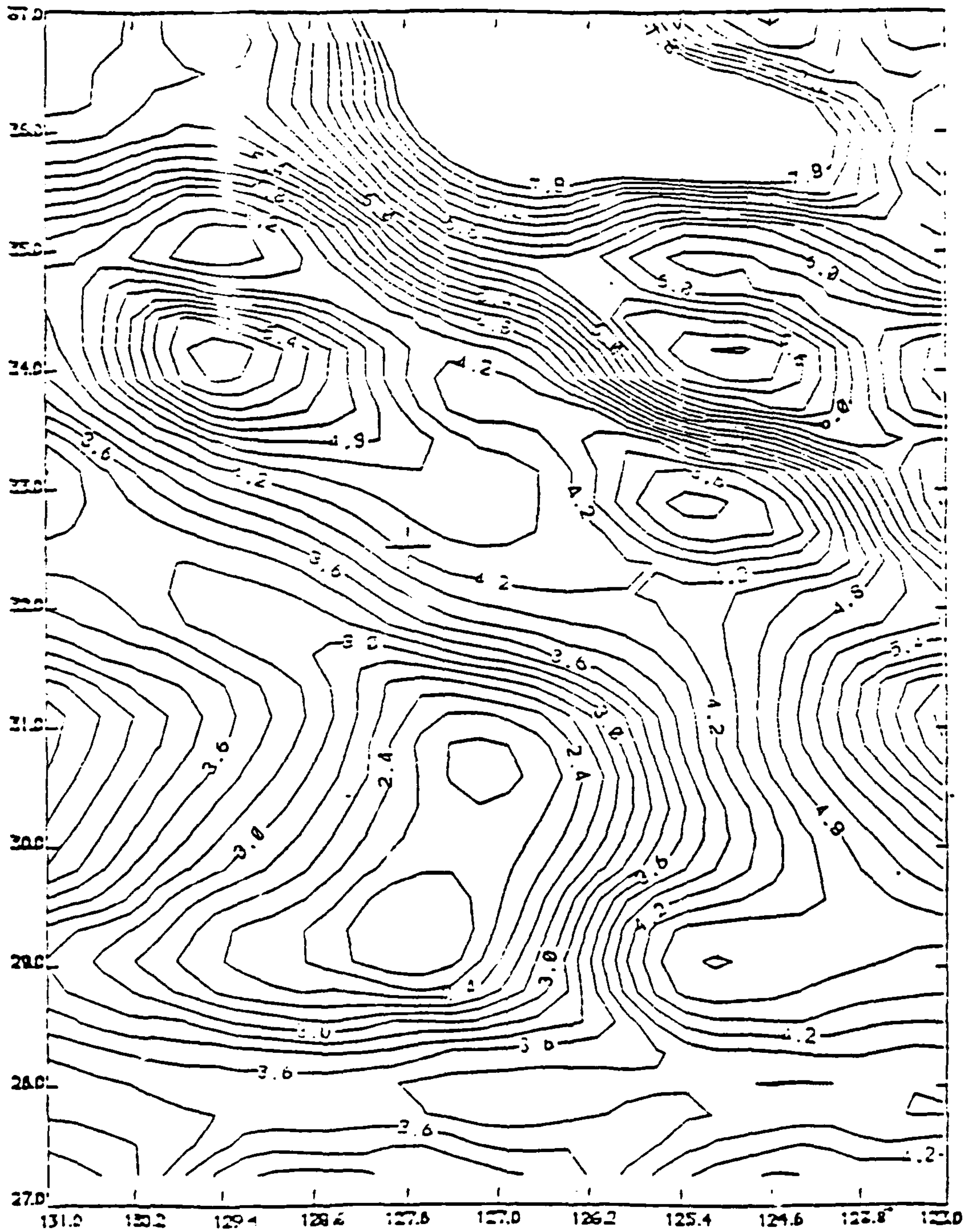


Fig. 2

RMS(fall) of sea surface height differences



CONTOUR FROM 2.0000 TO 7.8000 CONTOUR INTERVAL OF 0.20000
X INTERVAL= 0.80000 Y INTERVAL= 1.0000

Fig. 3

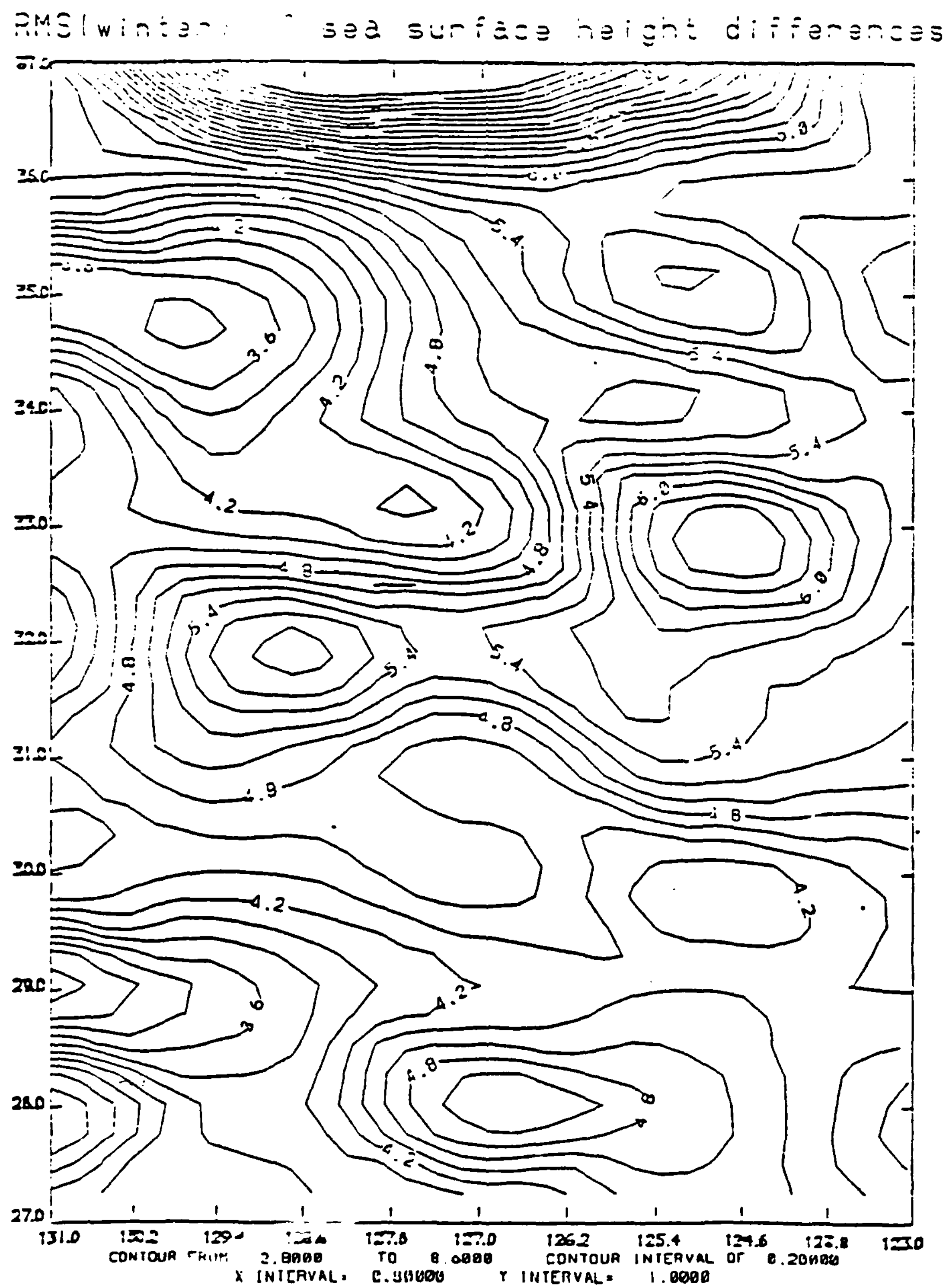

RMS(winter) sea surface height differences
27.0
28.0
29.0
30.0
31.0
33.0
34.0
35.0
36.0
131.0
129.4
127.8
127.0
126.2
125.4
124.6
123.0
CONTOUR FROM 2.8000 TO 8.6000 CONTOUR INTERVAL OF 0.20000
X INTERVAL= 0.80000 Y INTERVAL= 1.0000
3.6
4.2
4.8
5.4

Fig. 4

RMS(spring) of sea surface height dif ences

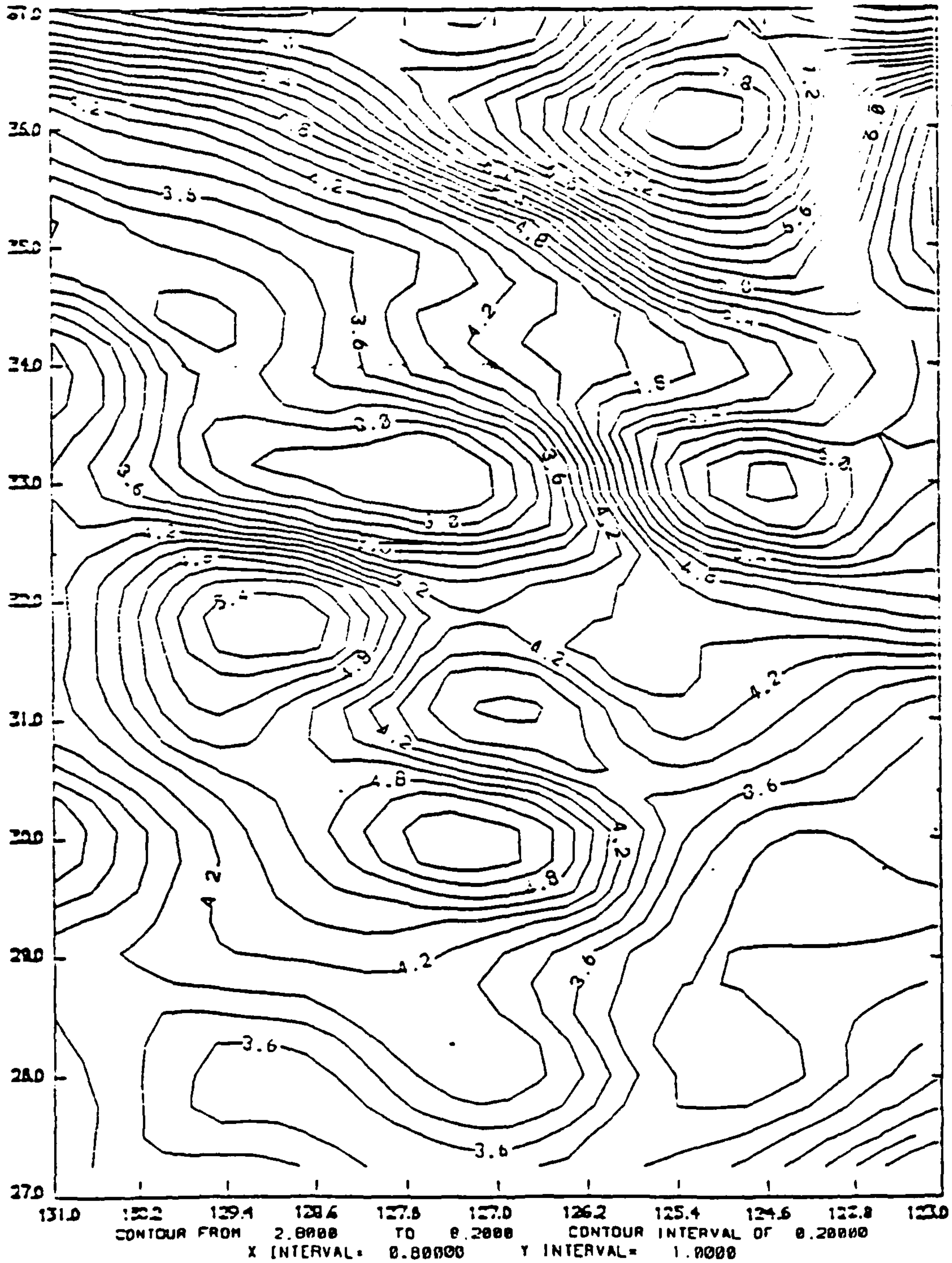
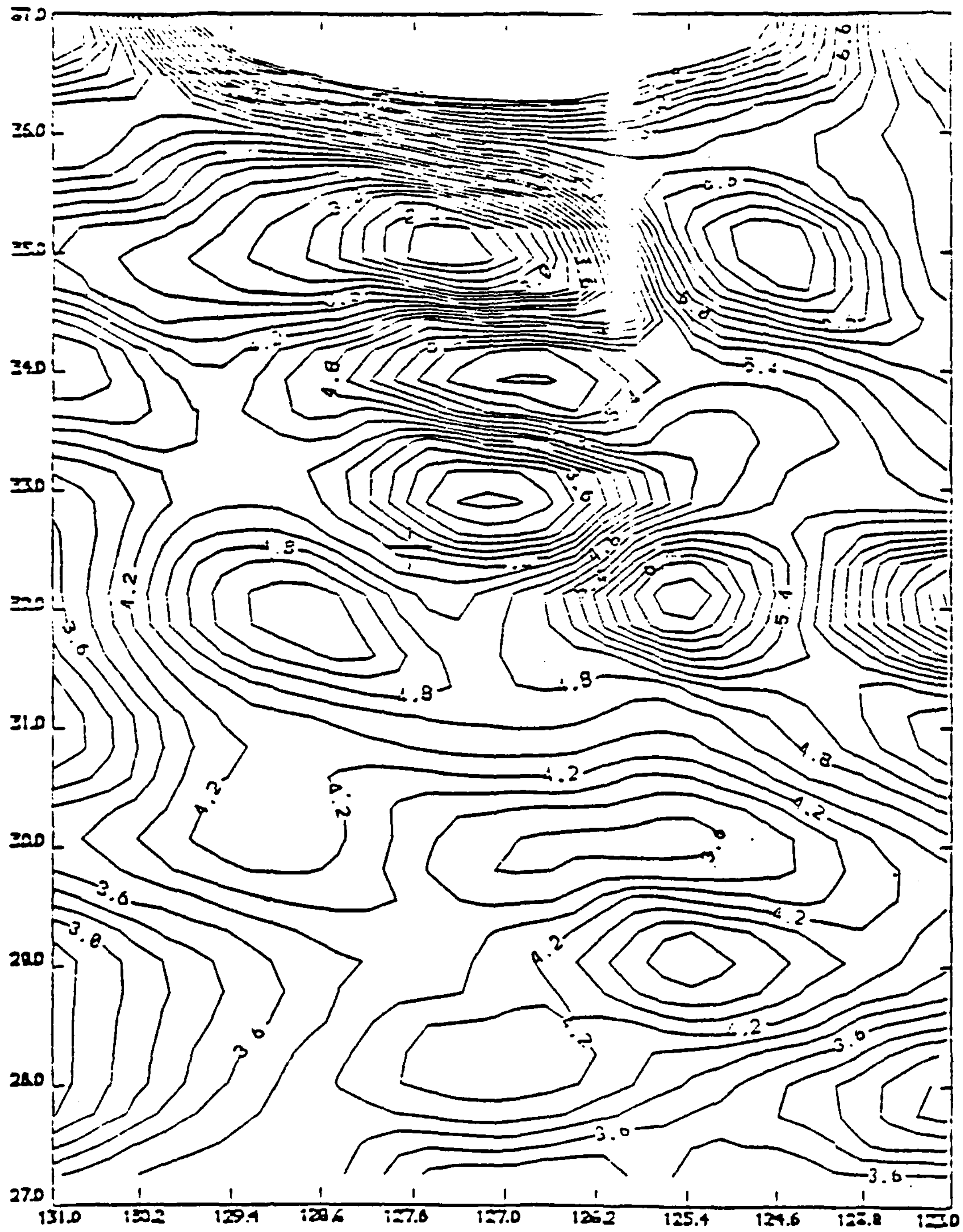


Fig. 5

RMS(winter 86-87) of sea surf height dif ences



CONTOUR FROM 2.2000 TO 8.0000 CONTOUR INTERVAL OF 0.20000
X INTERVAL= 0.80000 Y INTERVAL= 1.0000

Fig 6

RMS(winter 87-88) of sea surface height differences

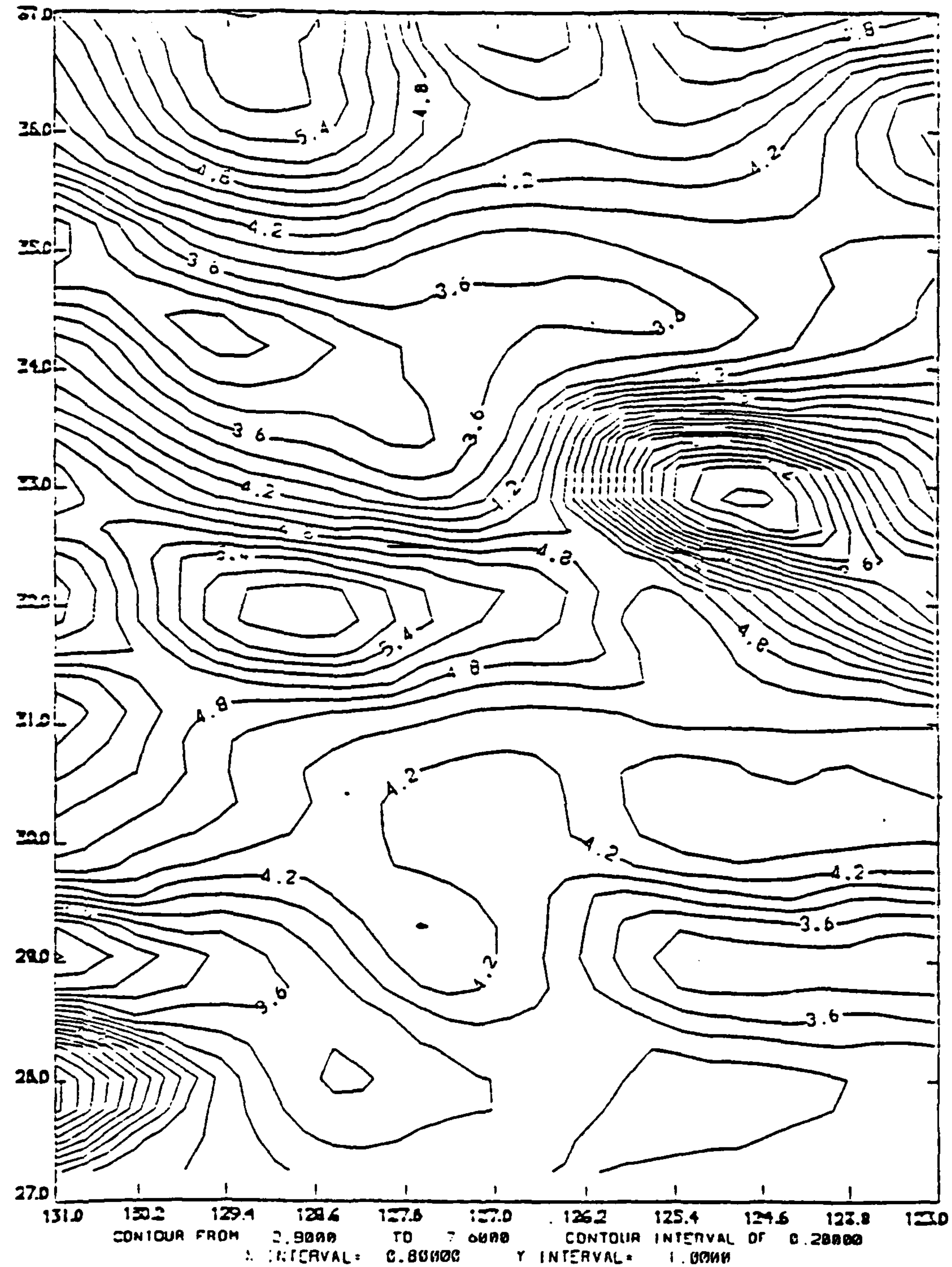
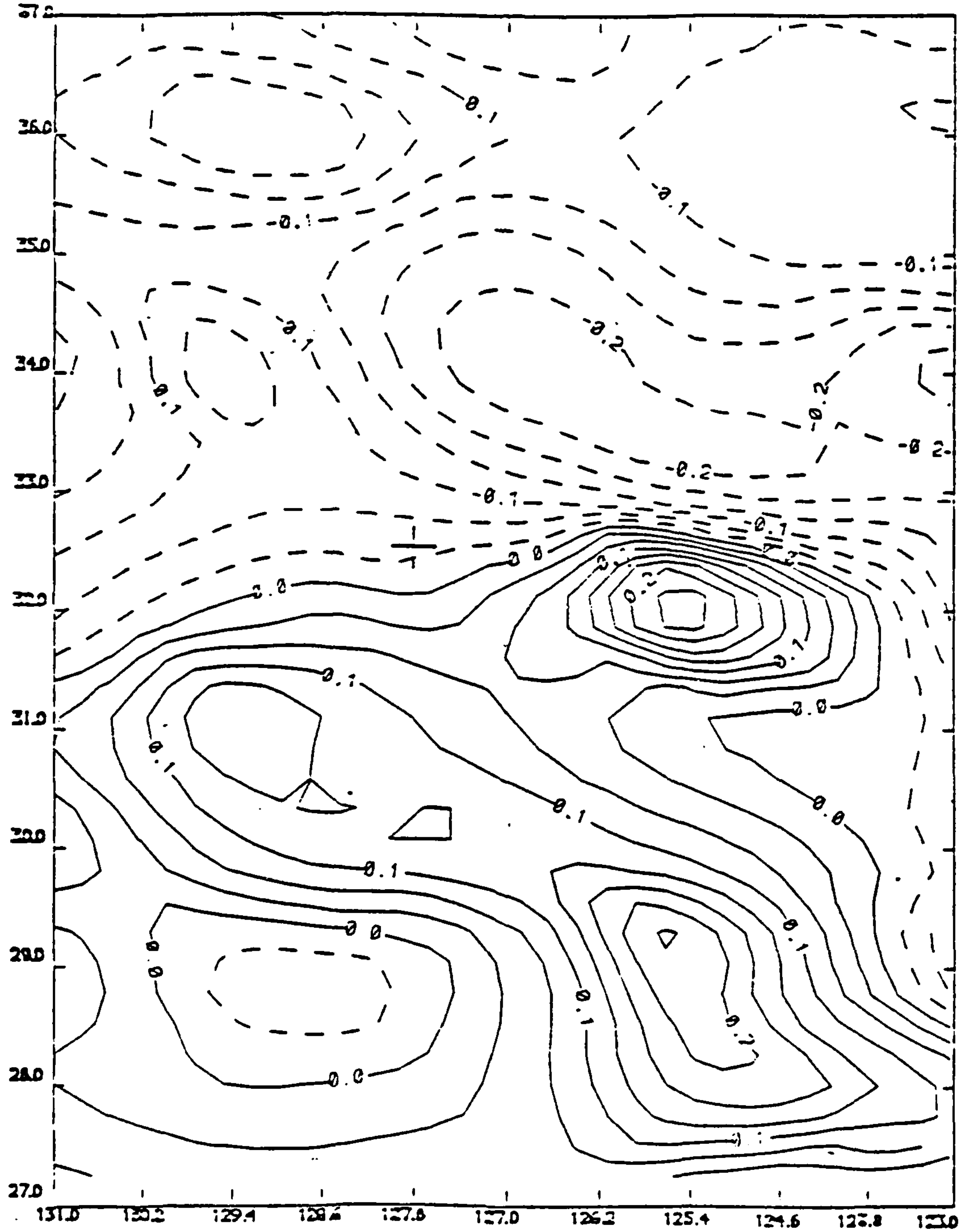


Fig. 7

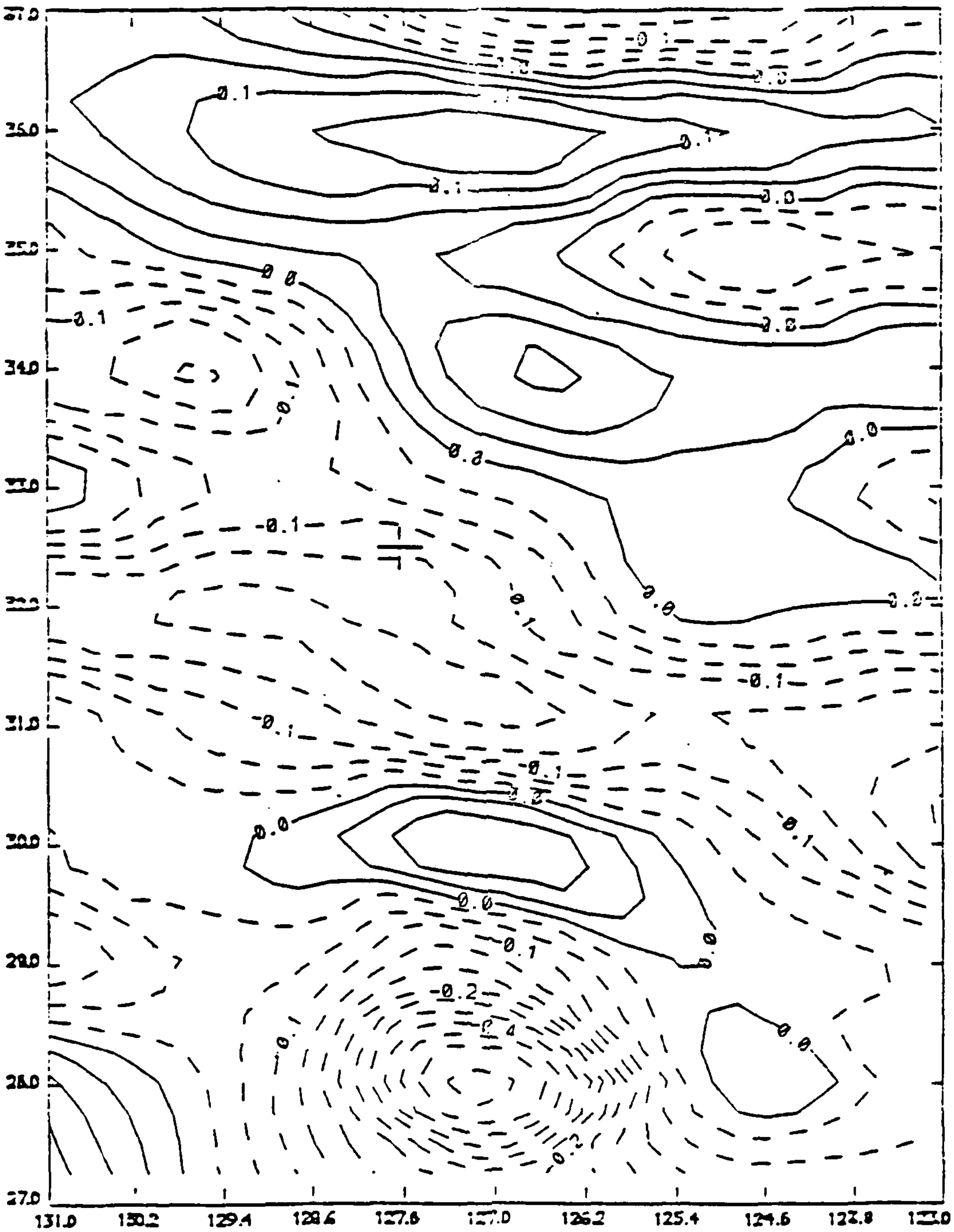
First Orthogonal



CONTOUR FROM -0.28000 TO 0.28000 CONTOUR INTERVAL OF 0.40000E-01
X INTERVAL= 0.80000 Y INTERVAL= 1.0000

Fig 8

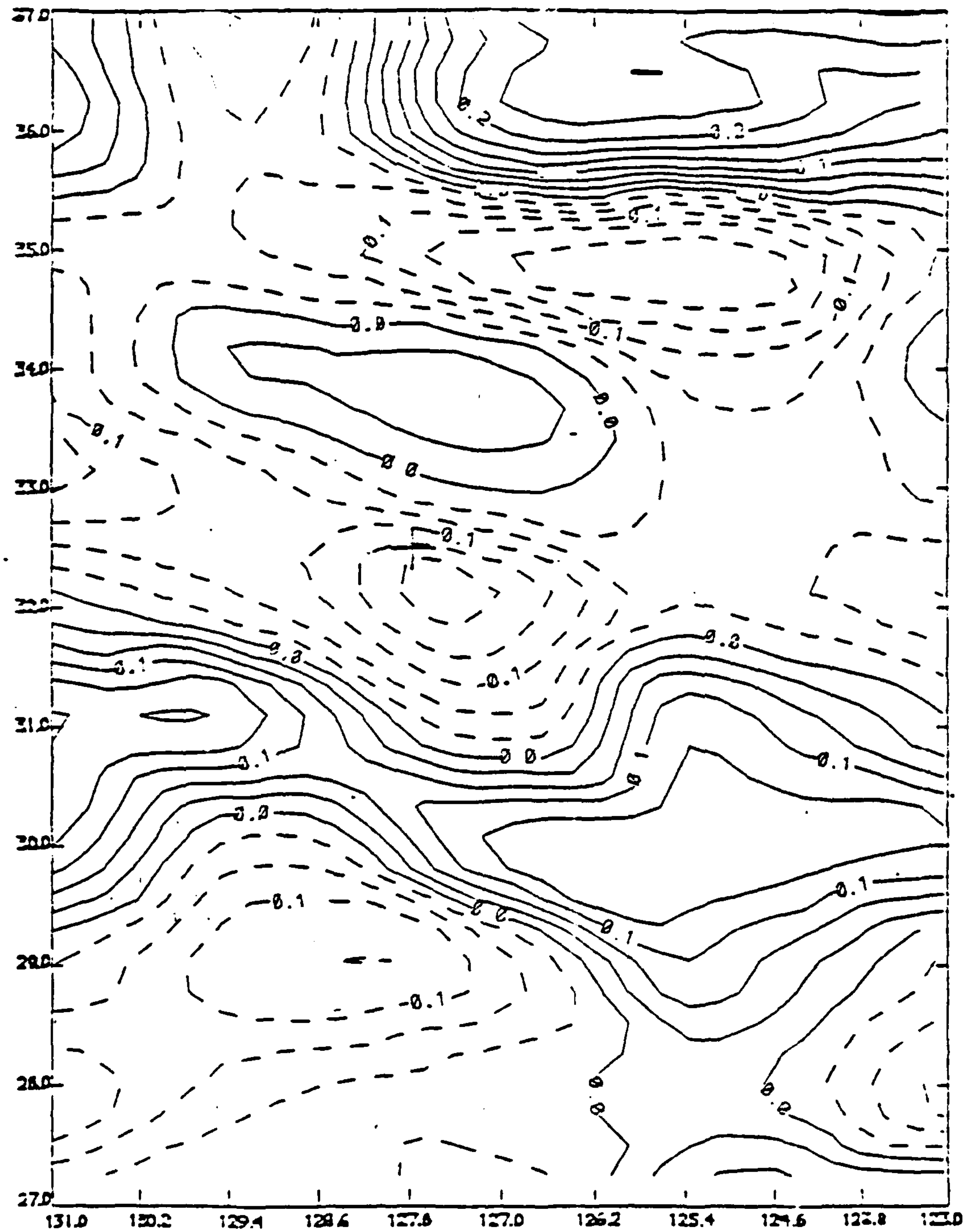
Seconc thogonal



CONTOUR FROM -0.48000 TO 0.20000 CONTOUR INTERVAL OF 0.40000E-01
X INTERVAL= 0.80000 Y INTERVAL= 1.0000

Fig. 9

Third Or[illegible]hogonal



CONTOUR FROM -0.20000 TO 0.32000 CONTOUR INTERVAL OF 0.40000E-01
X INTERVAL= 0.80000 Y INTERVAL= 1.0000

Fig. 10

Frequency-Wavenumber Spectra

Latitude = 32 N

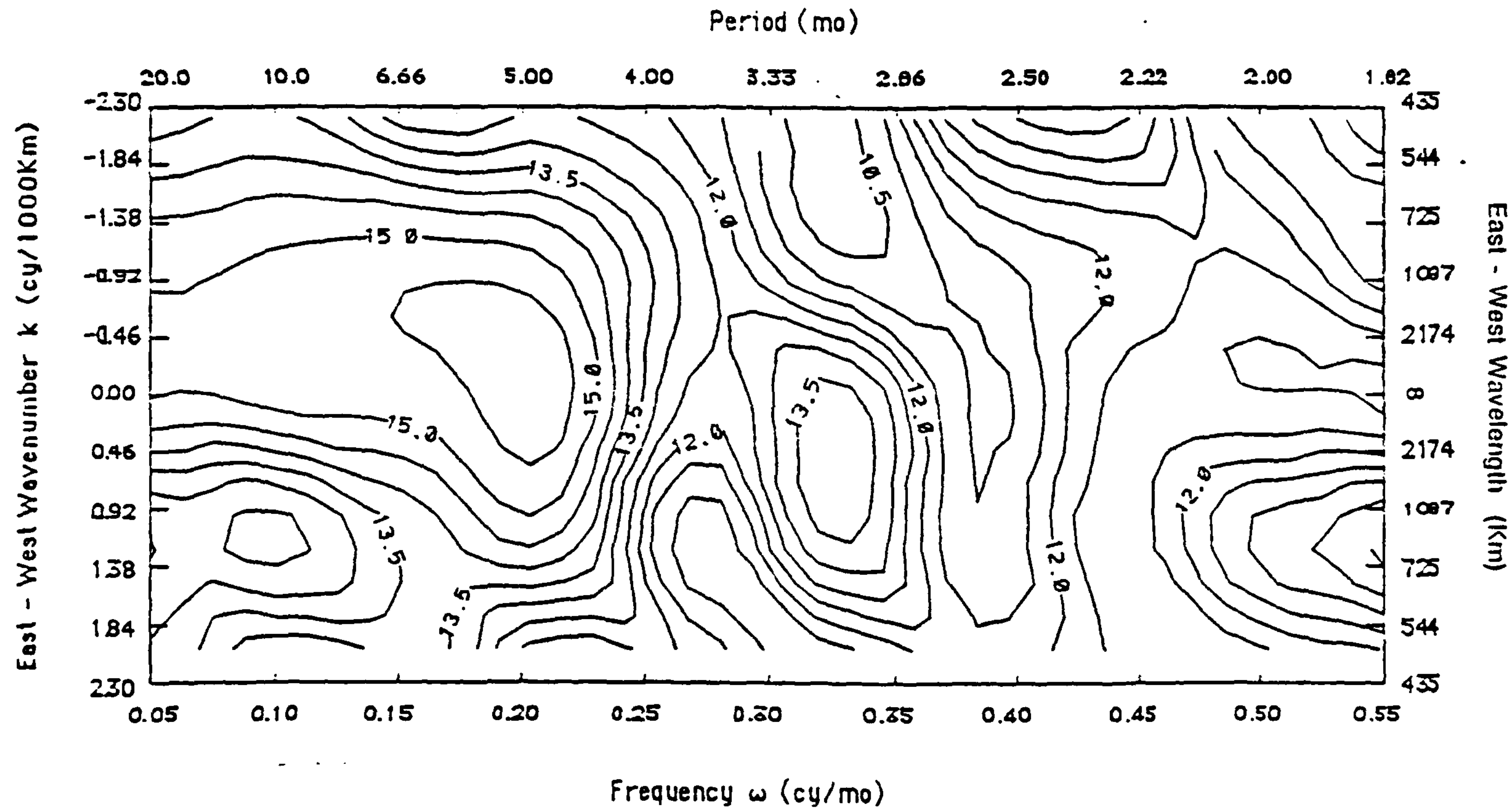


Fig. 11

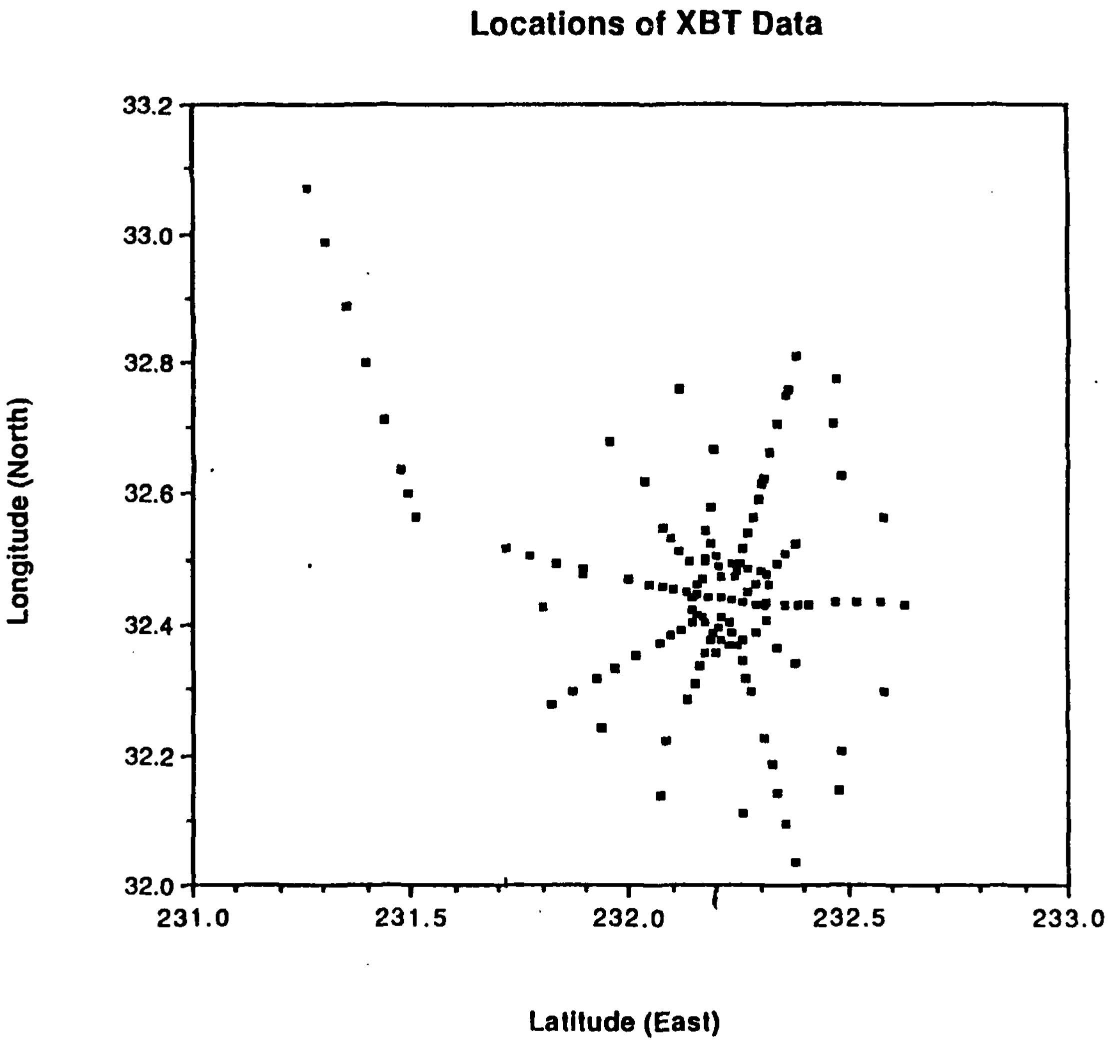
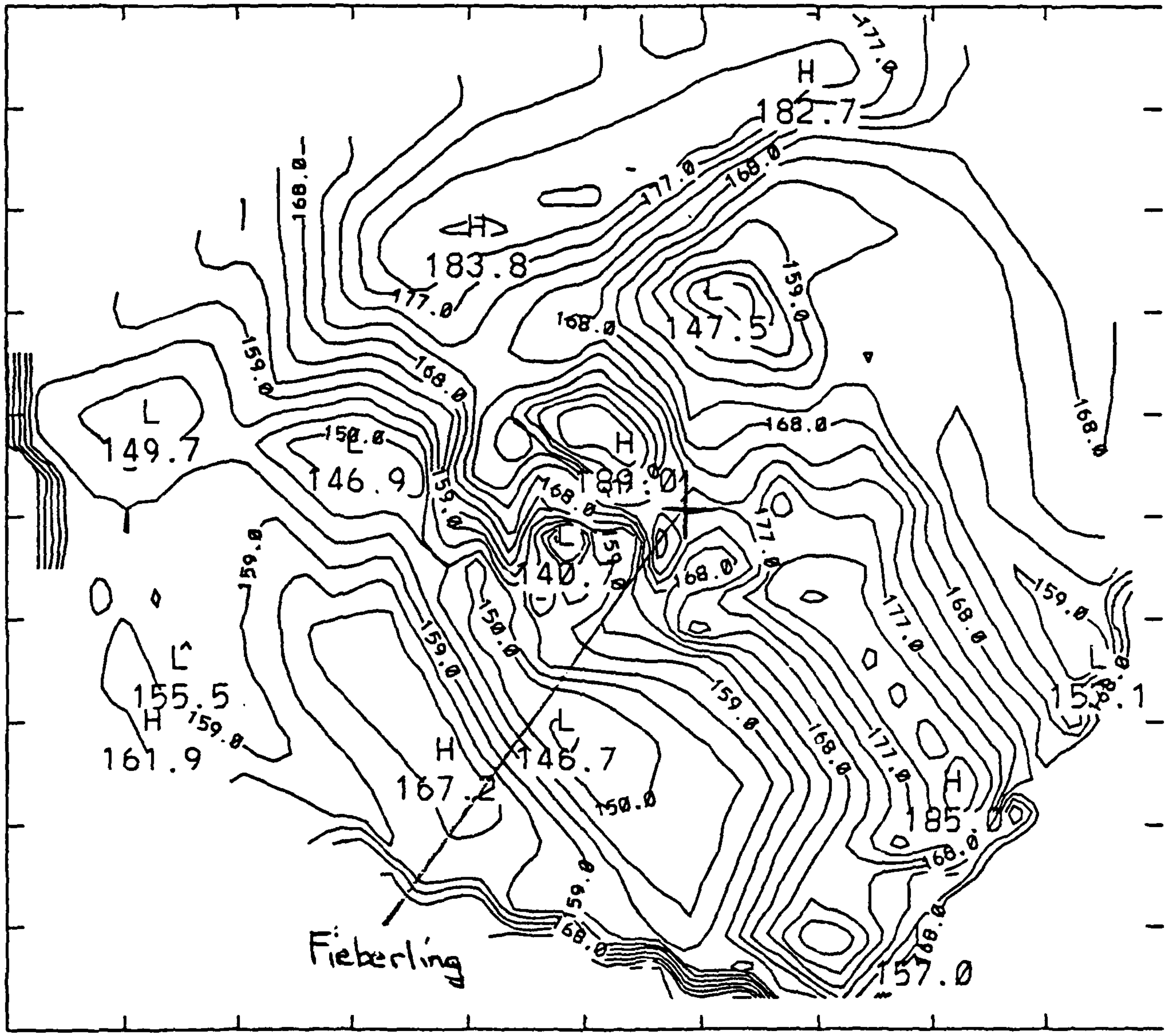

Locations of XBT Data
33.2
33.0
32.8
32.6
32.4
32.2
32.0
231.0
231.5
232.0
232.5
233.0
Longitude (North)
Latitude (East)

Fig. 12

XBT Survey May 18-22, 1989

Depth of the 12°C Isotherm



CONTOUR FROM 138.00 TO 195.00 CONTOUR INTERVAL OF 3.0000
X INTERVAL= 0.90800E-01 Y INTERVAL= 0.77500E-01

Fig. 13

Dynamic Height : Reference Level = 400m

Using Temperature - Salinity Table

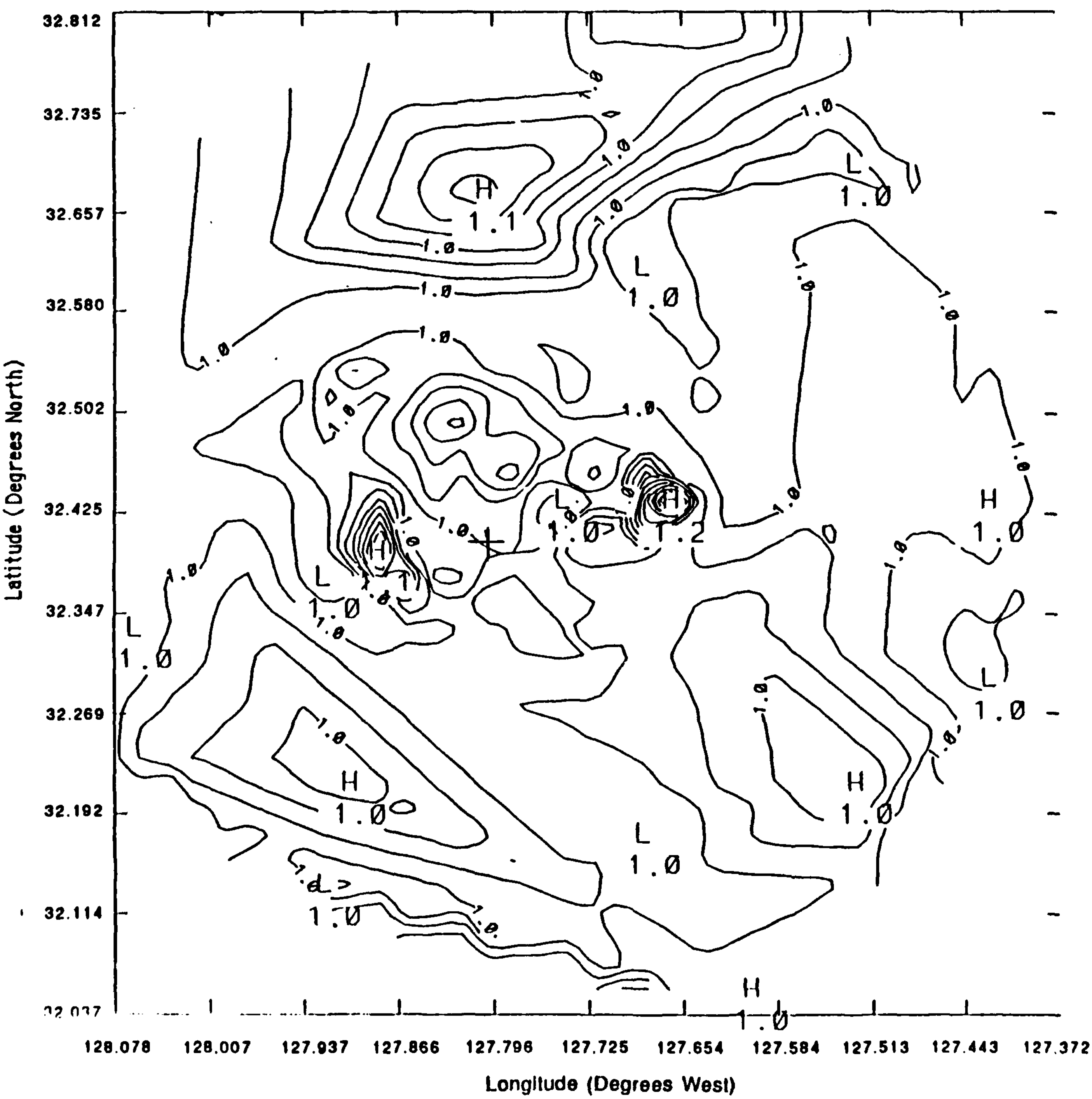
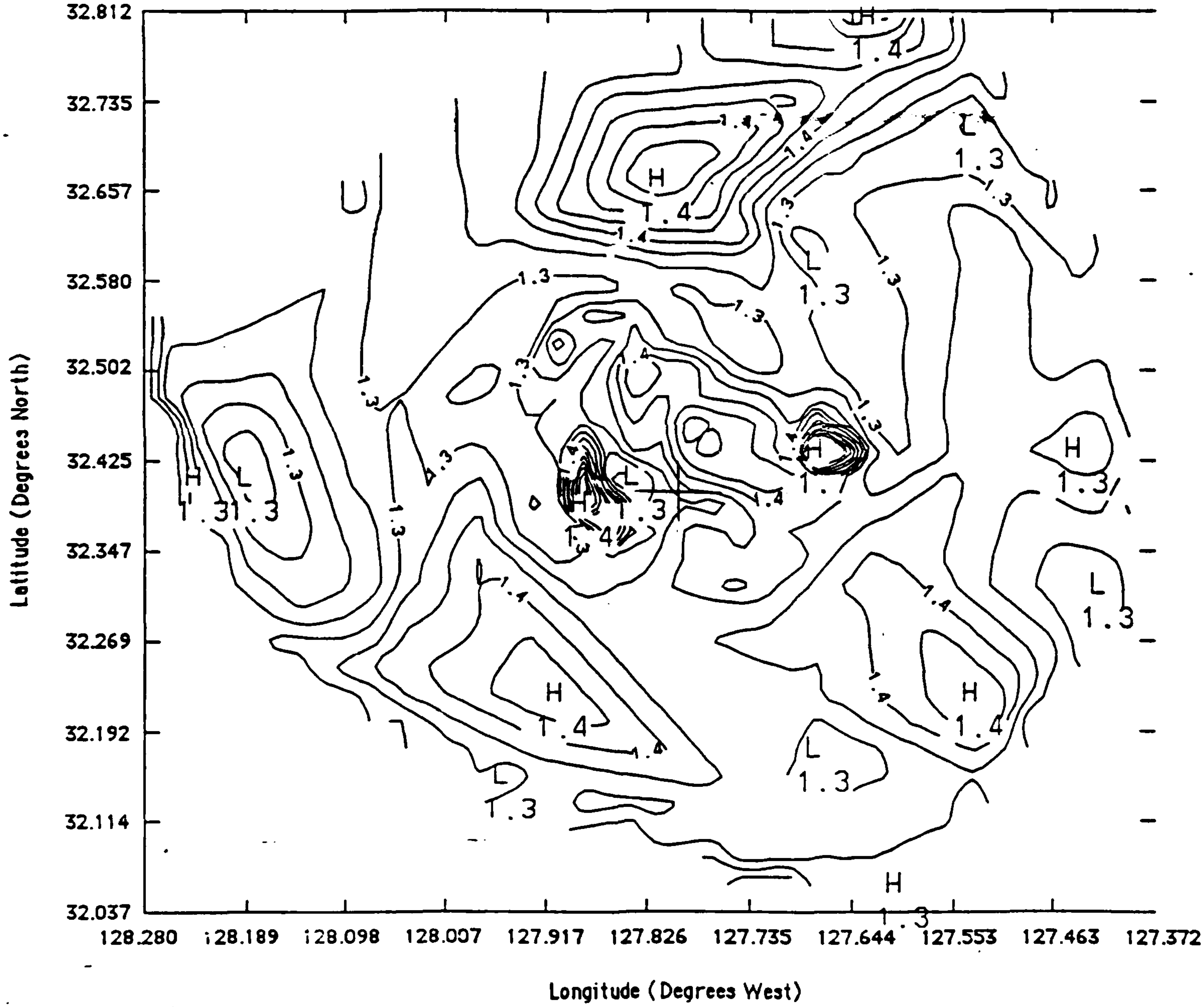


Fig. 1A

Dynamic Height : Reference Leve: = 700m

Using Temperature - Salinity Table



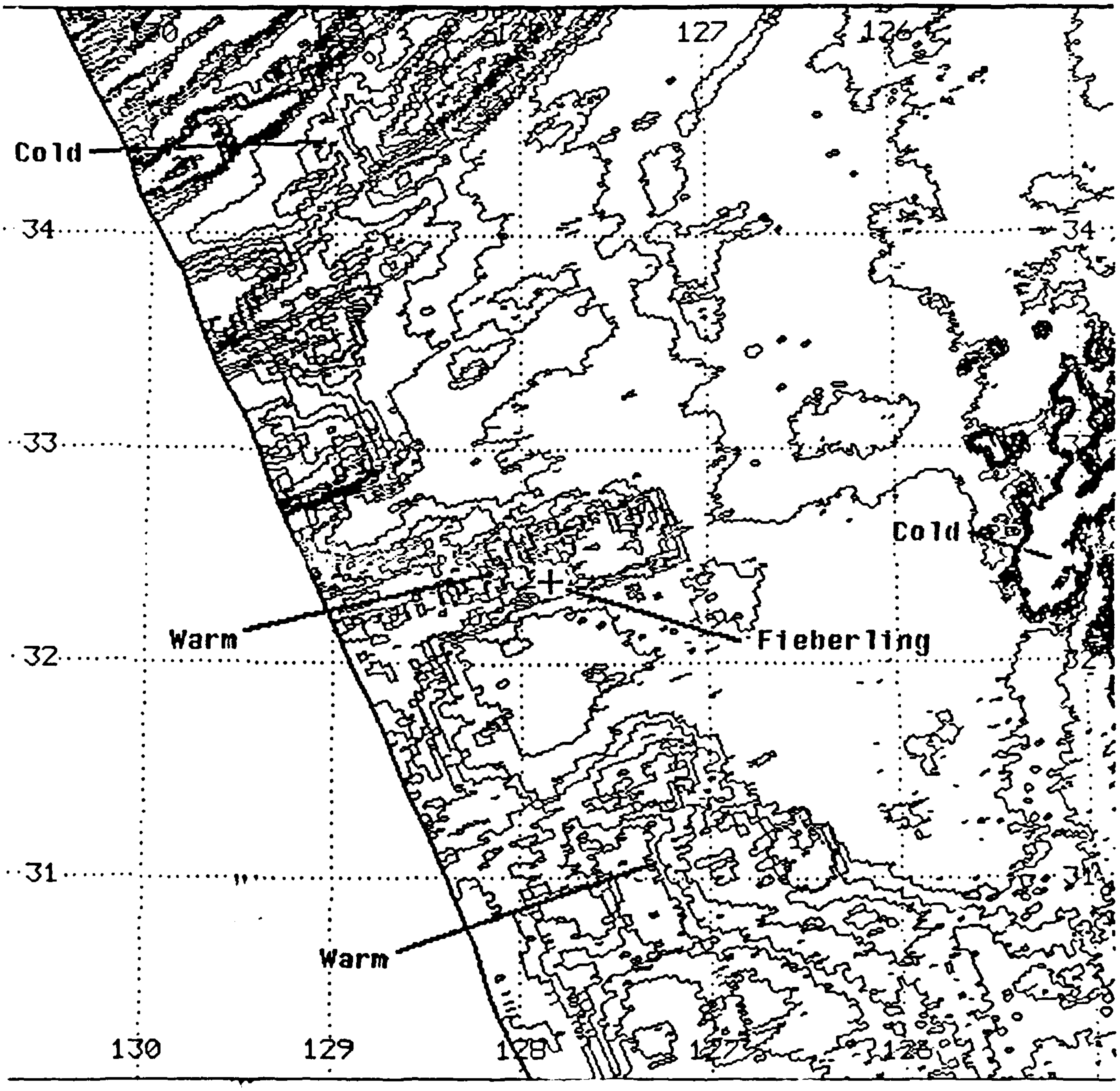

127
126
Cold
34
34
33
Cold
Warm
Fieberling
32
31
Warm
130
129
128
127
126

Fig. 16a

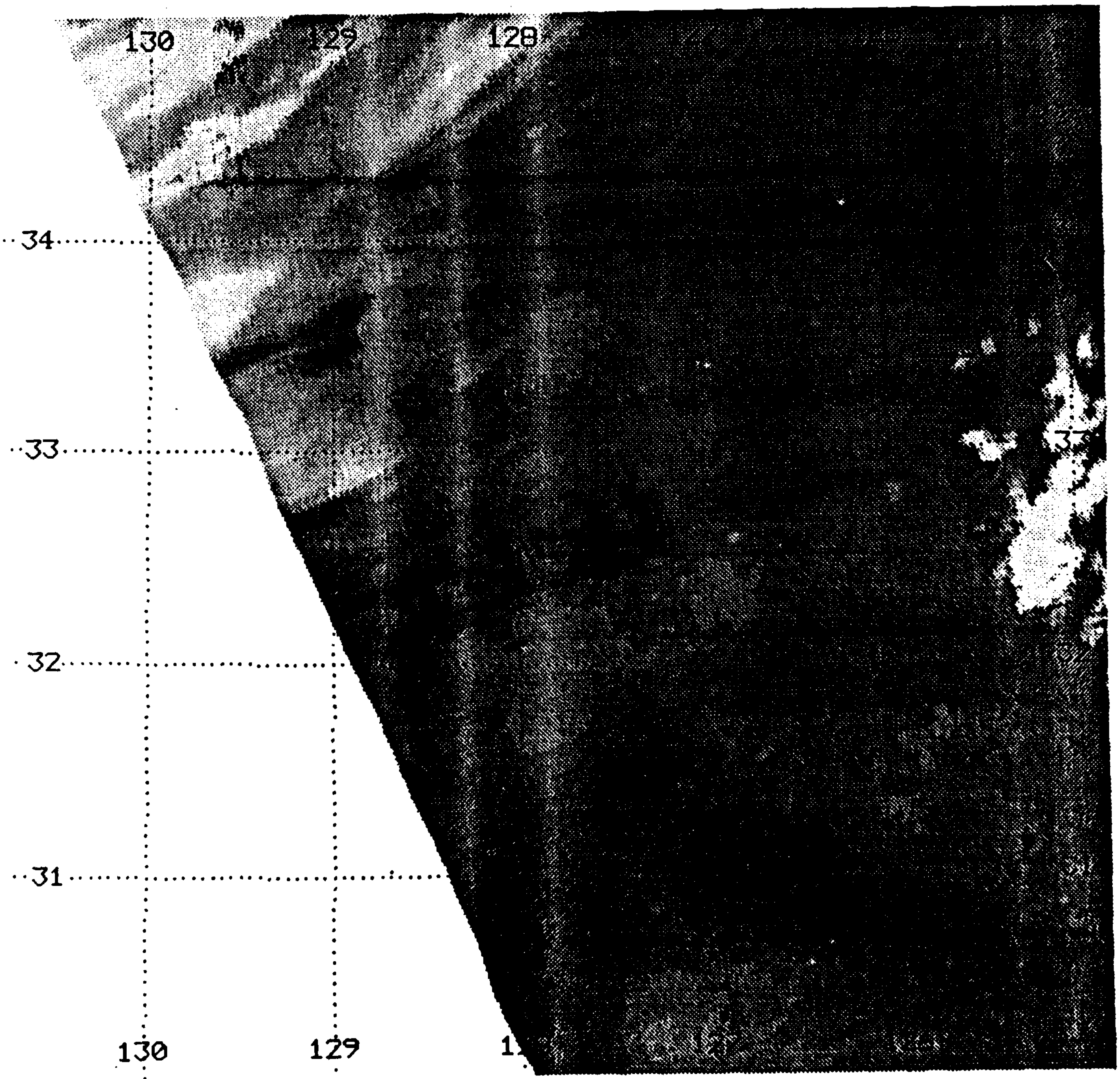


Fig. 16b